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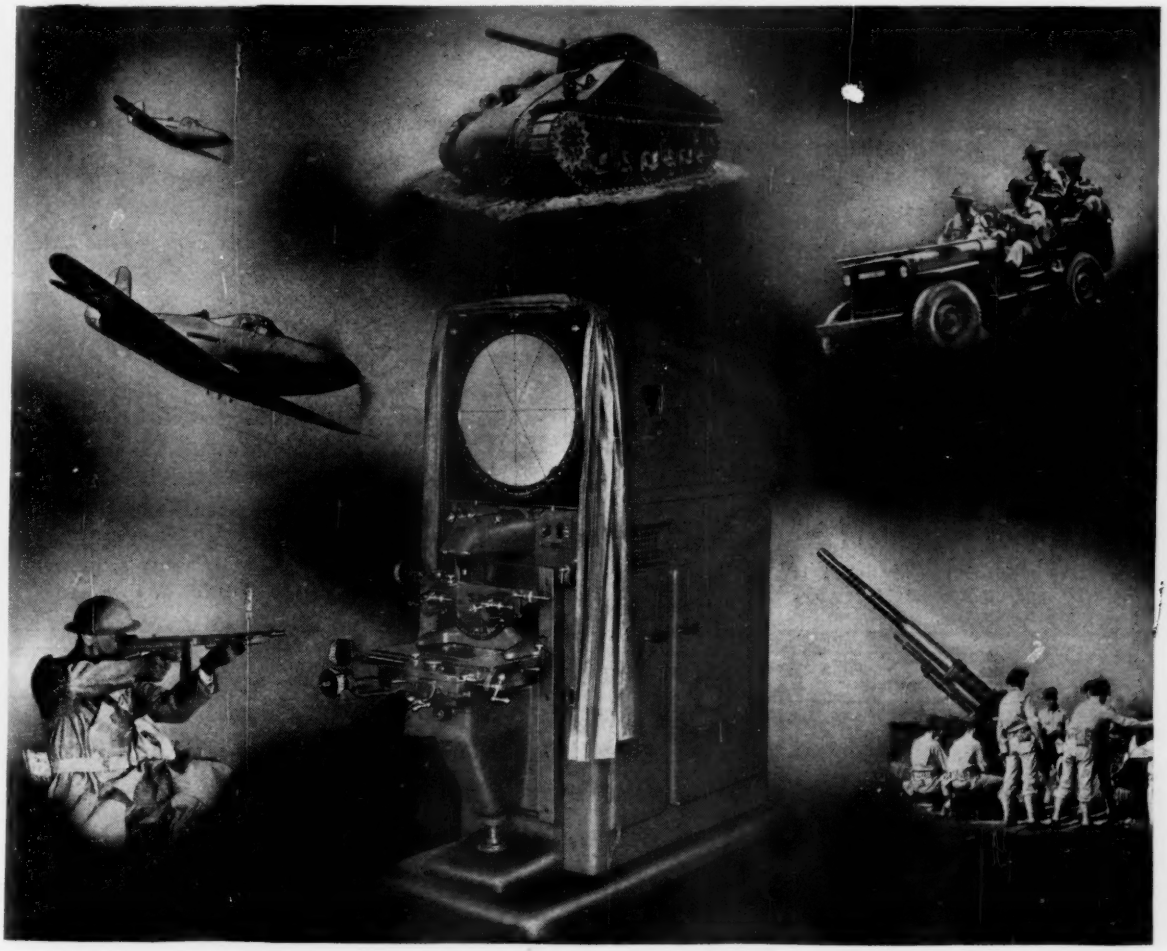

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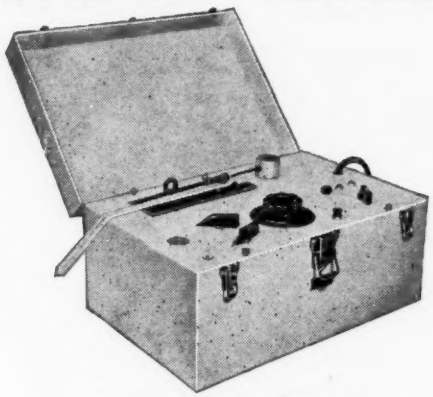

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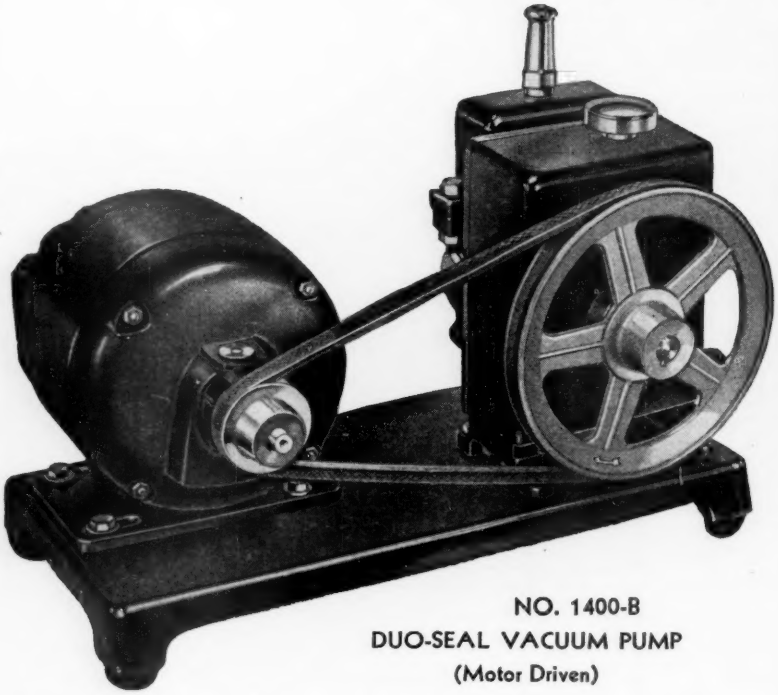

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DETERMINISM AND RESPONSIBILITY[1]

By Dr. HENRY NORRIS RUSSELL

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THERE is an old saying concerning the Christian ministry. "Every man must be an Arminian when he preaches, and a Calvinist when he prays." That is, in the first case he must emphasize free-will; and in the second, divine providence. This is far more than an epigram; it is an effective statement of an intellectual difficulty which besets religion, philosophy and science alike. Even the most case-hardened mechanist of the old nineteenth-century school had no qualms about asking his neighbor at table to pass the butter.

It is bold to attempt even a partial resolution of this ancient antinomy; but I am convinced that it may be very considerably clarified with the aid of concepts derived from physical science. In a round-table discussion, voices of protest would rise here. "Have you forgotten Heisenberg?" "Has not modern physics abandoned determinism, and committed itself to a principle of indeterminacy?"

Some ground must be cleared here before the discussion can proceed. It is not only in past centuries that mischief has been done by the unfortunate choice of a name. If the great physicist who discovered the "uncertainty principle" had only called it the "Principle of limited measurability" (as Max Born did a few years later) we might have been spared a great part of the "awful outbreak of intellectual licentiousness" which Bridgman all too truly foresaw among the half-informed.

The principle is of the type which Whittaker has recently called Postulates of Impotence.[2] Like New-

[1] A paper presented at the Third Conference on Science, Philosophy and Religion, New York, August 28, 1942.

ton's postulate, which amounted to denying the possibility of finding any unique state of absolute rest in nature, or Einstein's, which makes a similar denial regarding absolute motion, it has clarified so many difficult problems that it has won unanimous acceptance among physicists. Simply put, it denies the possibility of measuring the position and motion of any particle simultaneously and with perfect accuracy. The better we do with one, the less we must be contented with for the other.

The difficulty arises from the fact that the means of measurement themselves can not be refined to absolute perfection, because nature is not fine-grained enough. Matter, electricity and radiant energy all come in discrete packets—atoms, electrons, quanta—and no experiment can be made upon a single one of them except by hitting it with another, and thereby seriously disturbing the situation which we desired to study and measure.

There are many things which we physicists would dearly love to find out that nature won't let us—for example, what was the difference between the atom of radium which blew up last second and its neighbor, which will go on for centuries before undergoing the inevitable, but long-delayed, change.

We have no present hope of finding out why one atom disintegrates and not the other; but I, for one, am convinced that this does not justify us in saying that there is no reason. We must be agnostic about the question, but may not proclaim a negative dogma. The most that we can do is to say that, since no experiment made with the aid of anything known to exist in nature gives any hope of answering the question, it is "not physics."

One conclusion is clear. The nineteenth-century image of a vast, though finite, intelligence, which could determine at a given instant the exact positions and velocities of every particle in a (finite) universe, and their laws of interaction, and thus be enabled to predict with absolute accuracy the whole future history of the universe, is also "not physics." Such a perfectly detailed prediction of phenomena, even on the atomic level, is out of the picture.

Must we then be indeterminists? The only one I ever heard of was described to me by Dr. Watson, of the American University at Cairo. Visiting a date-grove, he asked his Mohammedan host, "What is the average life of a palm-tree?" and was answered "That will be known only after the Great Day of Judgment." His request for elucidation surprised the Moslem. "Surely you Christians believe, as we do, that all things are determined by Allah's Will." "Truly." "Then, when He says to a date-stone 'Spring up' a palm grows. When He says to that tree 'Die' it dies. Only when the Great Day is over, and the affairs of earth are ended, will it be possible to know what average age Allah, in His wisdom, has assigned to a palm-tree." Here is the true Indeterminist—an educated man, believing in an almighty, just and compassionate, though somewhat arbitrary, God—but not in the law of averages.

Hardly any philosophy could be more at variance with modern physics. There is very strong evidence that—though the individual quantum-jump is unpredictable, the distribution of the results of large numbers of them is strictly governed by the laws of probability. The average results for successive groups of the same number of cases, though not identical, differ from one another, and from a general mean value, by small percentages, which grow steadily smaller as the number of cases in a group is increased. The rare instances where single quantized events produce directly observable results, fluctuations in space and time are conspicuous—as may be seen by looking at the dial of a "radium watch" in the dark with a hand-lens. But, even here the apparent disorder of the unequal intervals has an underlying statistical order. Not only is the average value of the successive intervals substantially the same, for large groups, but the percentages of individual intervals which are (say) less than half, or more than twice the general mean, tend, for increasingly large samples, to definite values, predictable on well-known mathematical principles.

Most directly observable phenomena depend upon a number of atomic events which runs far beyond the possibility of counting in mere billions and trillions. In consequence, the statistical fluctuations in the averages of successive similar trials shrink below the limits of the best measurements and individual uncertainty is transformed into practical certainty. Strictly speaking, this is only a high probability; but the probability can be calculated and is so terrifically high that it is more impressive than any dogmatic assertion of certainty.

Take a very simple case—a glass globe containing 100 small smooth balls, just alike except that 50 of them are white and 50 yellow. If the globe is thoroughly shaken and set down, the balls will settle into a circular patch at the bottom. It might happen, by pure chance, that all the white balls fell into the north half of this patch, and all the yellow ones into the south half; but the probability of this is 2^{-50}, approximately one chance in 1,126,000,000,000,000. The thing might happen; but it would be throwing away money to bet one cent against the whole cost of the war that it would.

Before I can develop my main argument, I must ask you to go a bit farther with me into this strange territory, and consider the meaning of what are called "statistical properties."

[2] E. T. Whittaker, *Proc. Roy. Soc. Edinburgh*, 61: 168, 1942.

A classic illustration is the pressure of a gas. For several decades, in the actual growth of the science—and, for a few weeks, in an introductory course in physics to-day—a gas was, and is, regarded as an elastic fluid, filling uniformly the whole space between the walls by which it is confined, and exerting upon these walls a pressure (a force per unit of area) which is continuous—the same on all equal areas, however small, and at all times (so long, of course, as the general conditions are not changed).

Before the student's first year in physics is over he learns more. The gas is no longer regarded as a continuous medium, but as an assemblage of a vast number of molecules, flying about in every direction and rebounding from one another and from the walls. The impacts on the walls produce the pressure. Over sufficiently small areas of wall, and small intervals of time, they are not even roughly uniform; but for areas large enough, and times long enough to use in making ordinary measurements, they are so numerous that they average out to practically the same result every time.

Now the mathematical picture of the uniform continuous pressure is a very great deal simpler to work with than the innumerable individual impacts. Under ordinary engineering conditions the averaging-out process is statistically good to one part in a million or better. Consequently, the engineer adopts the simple generalized image of pressure with entire security that the calculations, based on it, will be as accurate as he ever needs them to be. From his standpoint, gas-pressure is an obvious reality.

But the physicist, or the technician, who works with a "high" vacuum, is in a very different position. He can make the number of molecules in his apparatus so small that the averaging-out process becomes trustworthy to only one part in a thousand, then one in a hundred, one in ten—and finally not at all. He has to think about the individual molecules and atoms if he is to make any sense of his observations—and when he does he gets results of practical value such as the tubes used in every radio set.

It can now be understood why a statistical property has some remarkable characteristics. (1) It is a creation of the human imagination designed to describe the relations of observed phenomena. (2) It is a simplified description of an excessively complex underlying situation. (3) It is of great theoretical and practical utility, both in science and technology. (4) Over a wide range of conditions it enables us to predict the results of experiment more accurately than we can hope to measure them. (5) Beyond the limits of this range, it gradually disagrees more and more with the facts.

Practically all the physical properties which we ordinarily attribute to material bodies, such as density, temperature, elasticity or surface tension, are statistical in nature. It is these properties which are connected by the familiar empirical "laws of nature" such as the laws of perfect gases, or those which govern the similar, but more complicated, behavior of steam. These laws express statistical relations, and predictions from them possess, not certainty, but a statistical probability which under ordinary circumstances comes to the same thing.

With these foundations laid, we may approach the problem of human conduct and responsibility.

Man is in part, at least, a physico-chemical system of extreme complexity. No attempt will be made here to discuss the question whether he is also, and essentially, something more and "higher"; but it will be profitable to explore some of the consequences of the hypothesis that man is entirely a physico-chemical system. This means that, given sufficient knowledge of the system and sufficient technical skill in analysis, it would be possible, by the methods of science, to deduce from the structure of the system the properties of human beings—whether physiological, psychological or social—unless, indeed, the investigation was blocked by the appearance of another postulate of impotence.

I am not asking you now to accept this hypothesis, but to consider its consequences, assuming that no impotence intervenes. Two conclusions may safely be drawn.

(1) The properties of mankind, predicted by such a theory, must coincide with the actual properties as revealed by empirical observation. New relationships among these might be opened up and old descriptive formulae superseded; but, if the theory predicted properties different from those which men actually have, it would be a bad theory, and the possibility of the physico-chemical explanation would be "not proven."

(2) The properties predicted by a successful analysis would be of the nature of statistical properties.

Among the most obvious and important properties of man is self-determination. Whether we consider the behavior of others or our own conscious experience, a great number of varied observational data may be reduced to order and empirically "explained" on the hypothesis that the normal human individual is a conscious person, possessing (within limits) intelligence and memory, and with a very considerable degree of control over his words and actions. We all act on these postulates every day—almost every hour—and it would be practically impossible to live through a day of normal human relations without acting on them. My old friend, Professor E. G. Conklin, tells of a conversation he once had with Jacques Loeb. "After he had vigorously denied the reality or possibility of human freedom, he saw his little son running down the steps with a large open

clasp-knife in his hand. At once he shouted, 'Bobby, close that knife. You might fall on it.' I said 'Now, Loeb, practice your philosophy' and in reply he merely winked one eye at me."[3]

It is an immediate consequence of these postulates that the normal individual may reasonably be held responsible for his voluntary actions. Without this principle, organized society could hardly exist.

This naive statement of the situation suffices to introduce the main point of my argument. If an interpretation of the human individual as a purely statistical system is assumed to be possible, then the empirical characteristics of consciousness, memory, reason, self-determination and responsibility must *ex hypothesi* appear as statistical properties of this system—or at least be capable of precise correlation with such statistical properties. Otherwise, the thing which the system represented would not be human.

If freedom and responsibility were statistical properties, we might expect them to have the distinctive earmarks of such properties. They are undoubtedly concepts of empirical origin and of very great theoretical and practical utility. Whether they are simplified descriptions of a complex underlying situation is not at present determinable beyond debate—we know too little of the nature of man.

But it is generally recognized that freedom and responsibility have their limitations. Some of these are purely intellectual—we are not free to imagine a polyhedron with plane faces and seven edges—and here the limitation is absolute, for we can prove that no such configuration exists.

But the responsibility to which a man might reasonably, or, if you will, justly, be held by a precise analysis, varies with the knowledge, intellectual capacity and often with the physical strength of the individual and, for the same individual, must take into account changes in health, fatigue, anxiety and a hundred other things. I owe again to Conklin the suggestion that responsibility fully assessed to the limit of its ethical significance is a continuously varying quantity. All men are equally responsible before the law—yes, because the portion of a man's whole range of moral responsibility to which the law fairly may—or actually can—hold him is so small a fraction of the whole that individuals who fall below this level may be regarded as defective. The law itself recognizes this exception.

At the limits of the field of responsibility we do not find a sharp boundary separating complete and absolute responsibility from its utter absence. There is, rather, a gradual falling off with changing circumstances—as is tragically illustrated by the progress of degenerative physical or mental disease.

More might be said if time permitted; but it is already evident that responsibility possesses the distinctive ear-marks of a statistical property, whether it is one or not—and the evidence in the case of freedom is similar.

I may now at last make bold to announce my principal thesis: The mechanistic hypothesis of the nature of man (in the statistical sense described above) is not an enemy, but an ally, of morals and religion.

I do not contend that this hypothesis is scientifically established—though the evidence in its favor appears to me to be strong;—and I leave its general philosophical implications to those versed in this discipline. But it goes a long way toward resolving the ancient dilemma of fate or freedom.

This takes its sharpest form when expressed in theological symbols—predestination versus free-will. In this presentation, indeed, it appears hopeless—an antithesis between human wills and a divine will, conceived as similar in nature, though with infinite wisdom and power behind it.

But, on the mechanistic hypothesis, the determinism enters through the structure of the underlying system, while freedom and responsibility are statistical properties of the assemblage, man. The antagonism is no longer acute, for one of the most distinctive features of the statistical properties of a system as a whole is that they can not be found in the characteristics of the individual particles which compose it. On the lower level of interpretation the statistical properties are not present. But on the higher level of integration they are the important ones, and suffice, in theory and practice, for the discussion and study of the system. Pressure, temperature, elasticity, and the like, are realities for the engineer. The physicist may use either terminology, according to the nature of his particular investigation; but he must be careful not to mix up concepts belonging to two different levels. It would be fatal, for example, to think of electrons shot out into a gas as if they were moving through a continuous medium; and to speak of the pressure or temperature of a single molecule in a gas is meaningless.

When considering the social, ethical, esthetic and religious relations of men, we start automatically on the higher level, and consciousness, reason, personality, freedom and responsibility are the concepts relevant to studies on this level. These studies are difficult enough, Heaven knows; but this is no reason why we should bedevil ourselves by introducing at one point, and at this point only, deterministic concepts belonging to a different level of interpretation.

The trouble comes from introducing determinism and rejecting freedom and responsibility while retaining other concepts belonging to the higher level, such as consciousness and personality. It is imaginable

[3] *The Rice Institute Pamphlet*, 28: 218, 1941.

that to some vast Intellect, which saw through the desperate complexity of our nature, responsibility and freedom would be replaced by deterministic concepts, intricate beyond our very imagining. But there is every reason to suppose that personality and consciousness would also be replaced by similar unimaginables. To such an Intellect men might not appear to be persons either. Least of all would they be conscious automata.

The answer to the question, Which is the reality and which the illusion?—or, better, Which seems to be the illusion, and which the reality?—depends on the direction from which the problem is approached. To our hypothetical Intellect, the underlying complex would be the more real; but we, who approach things from the surface, see reality in the concepts that lie nearest us. These have value and importance to us, not because they are ultimate—if there be any ultimates—but because they are proximate. We needs must act as if they were real, and we are justified in doing so. Do you remember Kim and the Red Lama in the Himalayas? "Look and know illusion, *chela!* These are the true Hills!"

It is, of course, still hypothetical that such an interpretation of humanity is possible at all. But we know that there is a maze of subordinate levels—atomic, molecular, colloidal, cellular, physiological, psychical, and perhaps more—through which the way would be exceedingly difficult to follow, even if it were communicated to us.

Why, then, should we vex ourselves with such fine-drawn speculations? There are two strong reasons. First, the evidence in favor of statistical determinism in physical phenomena is overwhelming; and there is a great weight of physiological and psychological data which support the belief that we ourselves are not exempt.

The effects of certain drugs, and of some diseases, upon the higher aspects of personality provide the most appalling evidence. In a lighter vein, but provocative of earnest thought, is an old quip, from the days of Lister's medical teaching at Edinburgh: "No one ever died a triumphant death of trouble below the diaphragm."

These are but glimpses of a mass of evidence which puts the mechanistic hypothesis very seriously in court.

But the insistent problem, in times like these, is religious. There is no scientific difficulty in the belief that God, if He exists, controls the universe completely. Postulates of impotence need not be made concerning the Deity. It is hard to believe that a morally perfect God controls the world in which we struggle. But if we deny this—if God is not all-powerful—if the evil wills of "the rulers of the darkness of this world" are outside His control, then the victims of oppression are indeed of all men most miserable, and there is no ultimate security anywhere. If we have any religion at all, we will pray in these days—and it is to God Almighty that we must pray.

This faith—that God knows why He made the world this way, though we do not—has supported those who "subdued kingdoms, wrought righteousness . . . turned to flight the armies of the aliens." We need it desperately to-day, and we need equally faith in freedom.

May we not have both, and be spared one more chapter of the weary history of the warfare of science and theology, if we accept, tentatively at least, a mechanistic but statistical hypothesis of our own nature? I have tried to show that this involves no abandonment of belief in responsibility or freedom, and in another place[4] and at length, I have argued that it is fully consistent with belief in personal immortality. So far as I can see, the validity of intellectual and moral values is not impaired.

We have indeed to make one sacrifice; we will no longer be inclined to think of ourselves as irreducible spiritual units possessing some sort of ultimate reality independent of all else but God. But this hurts only our pride—and is likely to be good for us.

THE NEW YORK ZOOLOGICAL SOCIETY[1]

By Dr. HENRY FAIRFIELD OSBORN

Members and Friends of the Zoological Society:

You come here each year for better reasons than hearing a long formal, detailed summary of the past year's activities. This will find its proper place in the printed Annual Report to be submitted to you at a later date.

The past year, however, has been an extraordinary year—a year of war. I feel therefore that comments should be made to you as to the situation of the Society in wartimes; that I should touch upon two or three of the major highlights of the year just ended—also speak briefly of the future.

The outstanding fact is that the activities for which this institution is responsible appear to mean as much to the public in days of war as they do in days of peace. Consequently, we have undertaken to maintain all our normal activities throughout the past year not

[1] Address at the Annual Members' Meeting of the New York Zoological Society, on January 12, 1943.

[4] "Fate and Freedom," Yale University Press.

only in the operation of the Zoological Park but in the fields of education and research. Naturally, many obstacles have had to be overcome and many more await us, but we are determined to do everything in our power to continue to maintain these activities for the duration. Our endorsement and encouragement comes from the public itself—a visible and powerful growing public interest, the limits of which, I believe, we do not ourselves begin to measure.

Our scientific staff has been able to assist directly in a number of ways in the war effort, especially in the fields of marine intelligence and in medical problems. Forty-three members of our organization, including eleven trustees, are absent on military duty.

I will touch briefly on two or three of the highlights of the past year. The new farm exhibit has proved even more popular than we could have anticipated. More animals were taken out from behind the bars this last summer (the elephants and rhinoceroses) and interior improvements, notably those to the Bird House, were completed in December. It will of course not be possible to make improvements of any importance during this year, although a large number of minor betterments will be carried out.

In passing—we will open in April an event of an entirely new type. Mr. Liers is on our program to-night and he and his friends, the otters, will be with us for the season, giving a number of public showings every day. We believe that through these the public will gain a better understanding of the minds and manners of animals. Mr. Liers is not an animal trainer. He reasons with animals and lets them reason with him.

One field expedition was carried out—that under Dr. Beebe to Venezuela. We feel a debt of gratitude for the financial support given to this work by the Committee for Inter-American Cultural Relations, and also the generous arrangements made for Dr. Beebe and his staff at Caripito by the officials and organization of the Standard Oil Companies here and in Venezuela.

As to finances, we have no major complaint. We ended the year within our earned income. Somewhat surprisingly, considering war demands, the Society has received cash donations during the past year slightly in excess of $50,000. We have not thought it timely to enter into a general campaign for capital funds. Allow me, nevertheless, to remind you that this institution greatly needs funds for the fulfilment of its ultimate destinies in education, in research and in public service. It is not my business to suggest to you when and how to give!

As to the future, the Zoological Society is scheduled to receive a fund in excess of $3,000,000 under the terms of the Post War Program, as publicly announced by the Mayor on April 24, 1942. This will provide for the further modernization and development of the Zoological Park—the initial steps for such a program having been taken, you will recall, in 1939 with the drawing of plans for the African Plains Exhibit—and the building of a new Aquarium. In regard to the latter, we now have the opportunity of planning for an institution that will really do justice to the miracle of the life of the rivers, the lakes and the great oceans of this world. There is now available a plan and design fund of $60,000, of which the City has provided $40,000 and the Society $20,000. This year it is expected that an equivalent fund will become available from the same sources. Plans for both institutions are therefore now being put into the blueprint stage. (You can see, after this meeting in the exhibit corridor, projections of both of these major projects.)

What other destinies are there? Certainly the realization, we hope, of that most compelling and important idea—the establishment of a research center in the Zoological Park for the study of animal diseases in their relation to human disease problems. Sometime, somehow this must be accomplished. We further aim to create a dynamic and expressive conservation exhibit—an exhibit so designed that it will vividly carry to the public at large the message of the conservation of our natural resources. Our objectives include also the further extension of our educational work and of the research work which leads so definitely to the advancement of human knowledge.

I must not overstay my time. The other day, our guest speaker to-night sent me a quotation from a chemist—none other than Dr. Eliot, that great educational leader, late president of Harvard University. It runs as follows:

> The human race has more and greater benefits to expect from the successful cultivation of the sciences which deal with living things than from all the other sciences put together.

It is with such thoughts, such potentialities, such objectives in mind that this institution calls upon us for the best of our thoughts and of our energies.

OBITUARY

STEPHEN WALTER RANSON
1880–1942

Two days after he had reached his sixty-second birthday, Stephen Walter Ranson, professor of neurology and director of the Neurological Institute at the Northwestern University Medical School, died of coronary thrombosis on August 30, 1942. His wife, Tessie, and three children, Captain Stephen W. Ran-

son, Mrs. Margaret Jane Lacy and Miss Mary Elizabeth Ranson, survive him.

Dr. Ranson was born at Dodge Center, Minnesota, on August 28, 1880, the son of Dr. Stephen William and Mary Elizabeth Foster Ranson. After finishing Dodge Center high school in three years, he entered the University of Minnesota in 1898. Here he came under the influence of Professor J. B. Johnston, who stimulated in him an interest in the nervous system. At the end of his third year, he transferred to the University of Chicago. In 1902, he started graduate work at the University of Chicago, after receiving the A.B. degree from the University of Minnesota. He worked under the supervision of the late Professor H. H. Donaldson and received an M.S. degree in 1903 and the Ph.D. degree in 1905. His dissertation was entitled "Retrograde Degeneration in the Spinal Nerves." While a graduate student, he went to the St. Louis University School of Medicine and helped the late Professor A. C. Eycleshymer with the work in the Department of Anatomy there for part of the year of 1904. He served as a fellow in neurology at Chicago in 1904–1906 and was awarded the M.D. degree at the Rush Medical College in 1907. He completed a year's internship at the Cook County Hospital and had planned to establish a practice in Chicago. However, he was induced to take an appointment in 1908 as associate in anatomy at the Northwestern University Medical School by Dr. Arthur W. Meyer, who was then head of the department there. When Dr. Meyer left for Stanford the following year, Ranson accepted an appointment as assistant professor and acting head of the department. On August 18, 1909, he married Miss Tessie Grier Rowland, of Oak Park, Illinois, and their family circle was a happy and hospitable one. In 1910 he became associate professor and then in 1912 professor and head of the department of anatomy at Northwestern, where he served for the subsequent twelve years. He spent the year of 1910–11 at Freiburg in Professor Wiedersheim's laboratory.

In 1924, he went to the Washington University School of Medicine in St. Louis to become professor of neuroanatomy and head of the department of neuroanatomy and histology. He was extremely happy with this opportunity, which offered him a reduced teaching load and excellent facilities for research. However, he decided to return to the Northwestern University Medical School on the first of February, 1928, to become professor of neurology and the first director of the newly formed Neurological Institute there. He remained at Northwestern the rest of his life, where he devoted himself to building one of the most productive schools of neurology that has ever existed. Since 1929, the work of the institute has been collected in an annual volume and these volumes contain a formidable array of important contributions.

His own research is recorded in a bibliography of some 205 titles[1] and gives expression to his interest in the form and function of the mammalian system. He was interested throughout his life in the components of the peripheral cerebrospinal and the visceral nervous systems. His demonstration of unmyelinated nerve fibers as early as 1909 was given additional proof by his introduction of the pyridine silver technique in 1914, an important modification of one of Cajal's. After he found unmyelinated fibers in large numbers in sensory nerves, he devised experiments to show that they mediate pain sensation. His later experiments and those with the cathode ray oscillographic analyses such as made by Erlanger, Gasser, Bishop and others have supported his earlier work. Because he recognized unmyelinated fibers, his histological analyses of the peripheral visceral nervous system were much more complete than previous ones. His work on peripheral and central visceral afferent pathways and vasomotor centers in the medulla oblongata is included in his review on "Afferent Paths for Visceral Reflexes" in the first volume of *Physiological Reviews.*

For a period of years, he worked on the mechanisms involved in postural contractions and a study of postural reflexes. Ranson and his colleagues first became interested in the hypothalamic region for its significance in somatic motor integrations, for the study of which he introduced the Horsley-Clarke stereotoxic apparatus into his laboratory in 1930.

Later, he directed the attention of his laboratory toward the analysis of visceral responses elicited by stimulations in this region and of symptoms arising from lesions accurately placed by electrolysis. He and his co-workers investigated such problems as the significance of the hypothalamus and hypophysis in water exchange and the syndrome of diabetes insipilus, and of the hypothalamus to temperature regulation, obesity, sexual function, emotional expression, catalepsy and other abnormal conditions. The corpus striatum occupied much of his attention at the last.

His later work was reviewed in the following lectures: Weir Mitchell Oration (1934), Harvey Lecture (1936), the Dunham Lectures (1940) and Hughlings Jackson Lecture (1941). The volume of the Association for Research in Nervous and Mental Disease, "The Hypothalamus and Central Levels of Autonomic Function" (1940), was dedicated to him.

In addition to these contributions in the experimental field, Ranson was the author of the text-book, "The Anatomy of the Nervous System," the first edi-

[1] This bibliography has been published by H. W. Magoun, *Quart. Bull. of Northwestern Medical School,* Vol. 16, pp. 304–310, 1942.

tion of which appeared in 1920 and just before his death he had completed the seventh edition. This textbook has been an important factor in the development of neuroanatomy in a superior fashion in the United States. He was extremely conscientious as a teacher and his kindly and sympathetic manner will be remembered by many a student. On his return to Northwestern in 1928, he gave up undergraduate teaching.

Into the work of his laboratory, he attracted many students, both from this country and abroad. He stimulated teamwork, an intense interest in experimental work and the utmost loyalty. He has trained men who are now in teaching posts in anatomy and physiology in various institutions, and there are many in clinical medicine who spent time with him. His enthusiasm was infectious and his training rigid and demanding.

He was a trained morphologist with strong interests in physiological significance. He had a keen appreciation for the implications of his work to clinical neurology, but he did not swerve from his objectives in fundamental problems of morphology and physiology.

He was a fellow of the American Association for the Advancement of Science, and a member of the National Academy of Sciences, the American Neurological Association, the American Physiological Society and the American Association of Anatomists, of which he was president from 1938–40. He served for a number of years on the Committee on Nomenclature of the American Association of Anatomists and he was a member of the editorial board of the Archives of Neurology and Psychiatry. His medical fraternity, Phi Beta Pi, established an annual lectureship in his honor at the Northwestern University Medical School in 1929. He was elected to Alpha Omega Alpha while an undergraduate medical student.

Dr. Ranson was a dignified, modest and retiring man who felt keenly his responsibility for leadership for the advancement of knowledge in the neurological sciences. He did not hesitate to question dogma and didactic authorities and to stand his ground against attack and criticism. His interest was in establishing factual evidence rather than in selling himself. He worked diligently all his life, even to the detriment of his own health in later years. He was a devoted husband and father who found time to enjoy and contribute to the family circles.

The students who passed through his laboratory were extremely loyal to him and appreciated the fatherly interest he took in them. After they had left his laboratory, they continued to seek his help and advice and he always welcomed them. His accomplishments will live through time and his influence will be continued by his students and associates who have been keenly appreciative of his outstanding leadership and his high ideals.

JOSEPH C. HINSEY
CORNELL UNIVERSITY MEDICAL COLLEGE

HERBERT CLIFTON HAMILTON
1868–1942

HERBERT CLIFTON HAMILTON was born at Sandy Lake, Pennsylvania, on November 21, 1868. In 1897 he received his master's degree from the University of Minnesota in chemical engineering and immediately secured a position as chemist in the laboratory of a steel plant. After two years he joined the Parke, Davis and Company research staff as a pharmaceutical chemist and later took up pharmacological standardization work. His specialty was the study of germicides. Even after retiring on December 31, 1934, he continued germicidal studies at Pennsylvania State College and at the New York Experiment Station, Geneva.

He pioneered in the adaptation of biological assay methods to commercial use and contributed more than forty publications to that field of work. His studies involved disinfectants, insecticides, digitalis, ergot, hemostatic agents and posterior pituitary extracts.

Mr. Hamilton was a member of the American Chemical Society, the American Pharmaceutical Association and the American Public Health Association and attended many of their national conventions. He was associated with the Tenth Revision of the U. S. Pharmacopoeia as an auxiliary member of the committee.

His death occurred suddenly on November 13, 1942, as the result of an automobile accident.

OLIVER KAMM

RECENT DEATHS

DR. HOWARD HAWKES MITCHELL, since 1921 professor of mathematics at the University of Pennsylvania, died on March 13 at the age of fifty-eight years.

THE death at the age of sixty-seven years is announced of Dr. Frederick T. Van Beuren, Jr., president of the Morristown, N. J., Memorial Hospital since 1933. From 1921 to 1934 he served as associate dean of the College of Physicians and Surgeons of Columbia University.

ROLLO APPLEYARD, cable engineer, physicist and inventor, died on March 1 at the age of seventy-six years.

DR. R. R. MARETT, the anthropologist, rector of Exeter College, Oxford, died on February 18 in his seventy-seventh year.

A CABLE received by Yale University announces the death on March 6 at the age of seventy-two years of Dr. Arnold C. Klebs, Switzerland, specialist in medical and scientific bibliography.

SCIENTIFIC EVENTS

THE ROYAL OBSERVATORY AT THE CAPE OF GOOD HOPE

THE 1941 report of H.M. Astronomer at the Cape of Good Hope shows, according to *Nature*, only too clearly the impact of the war on South African astronomy. The reversible transit circle has been fairly fully employed in making 7,234 transit observations, including fifty-seven of the moon, which were undertaken in view of the fact that lunar observations have perforce been dropped from the restricted programs of many European observatories. With the Victoria telescope the stellar parallax program has been continued, 2,642 plates having been secured during the year. A new determination of the parallax of Proxima Centauri, the star closest to the sun, gives $0.763'' \pm 0.007''$, in good agreement with the previously accepted figure of $0.762'' \pm 0.005''$; this should be compared with the value $0.756'' \pm 0.007''$ for α Centauri. During recent years the number of plates used for a parallax determination has increased to thirty, taken over three years or more. This change is fully in accord with the experience gained in the cloudier weather (but better seeing) at Greenwich.

The photoheliograph record of the sun's disc has suffered somewhat from the shortage of fine-grain plates, but a record, either on lantern plates or faster emulsions, was obtained on 311 days. Observations of occultations by the moon indicate a correction of $0.77''$ to its ephemeris longitude, which is of course based on Brown's Tables. This correction is expected to reach zero in 1943. Cometary observations included the photographing of Comet 1941*c* (de Kock), which reached the second magnitude, and of Comet Cunningham, which did not live up to expectations and only just reached naked-eye brightness. The weather at the Cape over the year was cloudier than usual, rainfall being 40 per cent. above normal, as the result of considerable falls on a large number of days rather than excessive falls on a few days. Substantial observing losses through cloud were recorded in the programs of the Victoria telescope and of the photoheliograph, but in spite of the weather the increased efforts of a war-depleted staff actually raised the number of observations made with the transit circle.

NEW HABITAT GROUPS OF THE AMERICAN MUSEUM OF NATURAL HISTORY

FOUR new habitat groups at the American Museum of Natural History have been opened to the public in the Whitney Memorial Hall of Birds. These groups show the bird life, flora and terrain of the Solomon Islands, Fiji, New Caledonia and the Great Barrier Reef of Australia. The exhibits were dedicated on the previous day at informal ceremonies attended by a number of invited guests and representatives of the Whitney family.

Since the opening of the Whitney Memorial Hall in June, 1939, with the completion of the first nine groups representing land and sea birds, principally of eastern and Mid-Pacific islands, the museum has sponsored further expeditions to other parts of the Pacific in order to round out its collections of accessories for the remaining nine exhibits.

A large part of this material was collected in 1940 by the late Lieutenant Adam Bruce Fahnestock and his brother, Captain John Sheridan Fahnestock, on the Fahnestock-American Museum of Natural History Expedition to island areas of the far southern Pacific. All field studies, botanical specimens and other accessories from sites represented in the four new groups were collected and shipped to the United States before the *Director II* was wrecked and sunk off the Great Barrier Reef, Australia.

Construction of the new groups was made possible by the gifts of Major Cornelius Vanderbilt Whitney for the hall, which is a memorial to his father, Harry Payne Whitney, and his grandfather, William C. Whitney. The groups were planned and assembled by Dr. James L. Clark, head of the department of arts and preparation, under the scientific direction of Dr. Robert Cushman Murphy, chairman of the department of birds. The accessories and foregrounds of the exhibits were prepared by George E. Petersen, who also accompanied the Fahnestock expedition as technical field assistant. Raymond B. Potter, assisted by George Adams, mounted the birds for the groups.

These new groups, like the previously completed exhibits, carry out the general design of Whitney Memorial Hall, planned to give visitors the illusion that from the middle of the Pacific Ocean they are viewing scenes of birdlife in every direction for thousands of miles. From mountainsides, white sandy beaches, islands of black volcanic rock or guano cliffs, a common horizon of clouds and sky rises to the blue vault of the flying bird dome that forms the ceiling of the hall. Francis Leo Jaques, artist and well-known painter of birds, also painted the backgrounds for the latest exhibits.

The collection of material for the five remaining groups planned for completion of the hall has been postponed for the duration of the war.

THE NUTRITION FOUNDATION

GEORGE A. SLOAN, president of the Nutrition Foundation, has announced that the foundation has authorized grants for the coming year amounting to $148,550. The grants were made on the recommendation of the Scientific Advisory Committee. They include $110,700 for the renewal of twenty-eight projects supported during 1942 and $37,850 for fifteen new research projects. Mr. Sloan stated that $316,000 in research grants to forty universities have been made since the organization meeting a year ago.

Dr. Charles Glen King, scientific director, reported to the board that projects undertaken in 1942 had already brought results which may have an important bearing on the food problems of both civilians and the armed forces.

Institutions that have received new grants are the University of Wisconsin, Harvard University, the University of Toronto, Columbia University, the University of California, the Johns Hopkins University, New York University, Massachusetts State College, the University of Chicago, Yale University, Cornell University, Oregon State College and the Oklahoma Experiment Station.

Dr. O. C. Carmichael, chancellor of Vanderbilt University, and Dr. F. G. Boudreau, of the Milbank Memorial Fund and chairman of the Food and Nutrition Board of the National Research Council, were elected public members of the foundation. Dr. V. P. Sydenstricker, of the University of Georgia Medical School, was appointed a member of the Scientific Advisory Committee.

The Rev. Hugh O'Donnell, president of Notre Dame University, and Cason J. Calloway, of Hamilton, Ga., who are public members of the board, were elected vice-chairmen. Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, is chairman of the board.

The Container Corporation of America, Chicago, Ill., and the Pillsbury Flour Mills Company, Minneapolis, Minn., were elected founder members. The National Sugar Refining Company, New York, N. Y., P. Duff and Sons, Inc., Pittsburgh, Pa., R. B. Davis Company, Hoboken, N. J., and the Curtiss Candy Company were elected sustaining members.

New members of the board of trustees, representing the new members of the foundation, were announced as follows:

Ellsworth Bunker, president, National Sugar Refining Company, New York; Walter P. Paepcke, president, Container Corporation of America, Chicago, Ill.; William H. Duff, II, president, P. Duff and Sons, Inc., Pittsburgh, Pa.; B. E. Snyder, treasurer, R. B. Davis Company, Hoboken, N. J.; Philip Pillsbury, Pillsbury Flour Mills Company, Minneapolis, Minn.; Otto Schnering, president, Curtiss Candy Company, Chicago, Ill.

NOTICE TO ZOOLOGISTS

THE following statement has been sent to SCIENCE by the War Emergency Committee of the American Society of Zoologists, of which Dr. Carl G. Hartman, of the University of Illinois, is chairman.

As there is every prospect of a most acute shortage of teachers of physics, mathematics and chemistry, it is suggested that zoology teachers possessing a background of training in these branches send their names and a restatement of their pertinent, specific qualifications to the Roster of Scientific and Specialized Personnel, 10th and U Streets, Washington, D. C. It is further suggested that zoology teachers in the smaller colleges who can teach the elementary phases of one or more of these subjects and who can be spared by their own institution get in touch with the nearest institution selected by the Army and Navy for large-scale teaching in these subjects.

There is urgent need also for medical parasitologists and medical entomologists. Ph.D.'s in parasitology or in entomology who have had four years' combined graduate work and practical laboratory or field experience are also needed. (Entomologists with a master's degree and two and one-half years of field experience may also apply.) Men who can qualify in these fields will find there an opportunity for direct service in the war effort. In most cases substitutes probably can be found to free such specialists for the service. Men may be accepted whose physical qualifications require limited service. For further information concerning medical parasitologists, entomologists and biochemists write to Captain Geo. R. Packard, A.U.S., Philadelphia, Headquarters Officer Procurement, 2442 Fidelity-Philadelphia Trust Building.

THE NAVY COLLEGE TRAINING PROGRAM

MEN between the ages of seventeen and twenty who wish to take advantage of the new Navy V-12 college training program must take a qualifying test which will be given in schools and colleges throughout the nation on April 2.

Men selected as potential officer material under this program will be sent to college by the Navy for varying lengths of time and will receive $50 per month pay as apprentice seamen in uniform. Eligible men who do not take the qualifying test on April 2 will not have another opportunity to do so for six months.

Students selected on the basis of officer-like qualities, including test scores, will be assigned to the Navy college training program in two groups, the first group reporting about July 1 and the second group about November 1.

High-school seniors and recent alumni should get

in touch with the principal or superintendent of their schools regarding details of the examination. The tests also will be administered by colleges and universities to their own students and to other high-school graduates in the vicinity.

The following will be eligible to take the test on April 2:

High-school or preparatory school graduates who will have attained their seventeenth but not their twentieth birthdays on July 1, regardless of whether they are attending college;

High-school or preparatory school seniors who will graduate by July 1 and who will be seventeen but not twenty years old at that time;

Students who are not high-school graduates, but who are continuing their education at an accredited college or university (the same age limits as above).

THE COPERNICAN QUADRICENTENNIAL

PROFESSOR HARLOW SHAPLEY, director of the Harvard Observatory, has accepted the chairmanship of the Copernican Quadricentennial National Committee, now being formed under the sponsorship of the Kosciuszko Foundation, of which Dr. Stephen P. Mizwa is director, to facilitate plans for the nation-wide commemoration of the four hundredth anniversary on May 24 of the death of the great Polish astronomer, Nicholas Copernicus, and of the publication of his masterwork, "De Revolutionibus Orbium Coelestium."

A meeting will be held on the evening of May 24 in Carnegie Hall, New York City, at which Professor Shapley will preside. A number of distinguished speakers, including His Excellency, Jan Ciechanowski, Ambassador of the Republic of Poland to the United States, will take part.

One of the most interesting features of the quadricentennial will be participation by the nation's leading planetariums. The Hayden Planetarium, at the American Museum of Natural History in New York, of which William H. Barton, Jr., is curator, will present a special planetarium program during the month of May, depicting the Ptolemaic and Copernican conceptions of the solar system.

Arthur L. Draper, director of the Buhl Planetarium and Institute of Popular Science at Pittsburgh, plans to exhibit in the Hall of Astronomy whatever exhibits are available and pertinent.

The Fels Planetarium of the Franklin Institute in Philadelphia, of which F. W. Schlesinger is director and Dr. Roy K. Marshall is assistant director, are planning a planetarium demonstration of the solar system, paying tribute to the life and works of Copernicus. This lecture demonstration will be entitled "Systems of the World," based upon Galileo's famous "Dialogue on the Two Chief Systems of the World," written in 1632. Rare library copies, owned by the Franklin Institute, of the first and second editions of Copernicus's "De Revolutionibus" and a first edition of Galileo's "Dialogue" will be on display. The Polish flag will fly above this case of books and other forms of tribute will be paid to the Polish Allies. On the evening of May 24, it is planned to have a special "Polish Night" at the Planetarium.

Dr. C. H. Cleminshaw, acting director of Griffith Observatory in Los Angeles, and Mrs. Grace P. Johnson, director of the Museum of Natural History of Springfield, Mass., also will arrange planetarium programs.

SCIENTIFIC NOTES AND NEWS

DR. ARTHUR B. LAMB, professor of chemistry and dean of the Graduate School of Arts and Sciences of Harvard University, was presented on March 5 with the William H. Nichols Medal of the New York Section of the American Chemical Society for 1943 at a joint meeting of the section and the Society of Chemical Industry. The medal was awarded in recognition of "his investigations in inorganic and physical chemistry, his leadership in defense against poison gas, and as a teacher, administrator and editor." Professor Lamb's address was entitled "The Role of the *Journal* of the American Chemical Society in the Furtherance of Chemical Research in America." He has been the editor of the *Journal* for twenty-six years. Among the speakers who paid tribute to Dr. Lamb and his work were Dean Frank C. Whitmore, of Pennsylvania State College; Professor James W. McBain, of Stanford University, and Dr. Charles N. Frey, chairman of the New York Section, who presided.

THE three hundred and eighteenth meeting of the Washington Academy of Sciences, which was held on March 18, was devoted to the presentation by the academy of its awards for scientific achievement for 1942. They are as follows: In the biological sciences, to Robert S. Campbell, U. S. Forest Service, "in recognition of his distinguished service in range research, particularly in the development of range utilization standards"; in the engineering sciences to Walter Ramberg, National Bureau of Standards, "in recognition of his distinguished service in research on the static and dynamic strength of structural elements, particularly in relation to aircraft," and in the physi-

cal sciences to Milton Harris, National Bureau of Standards, "in recognition of his distinguished service in conducting fundamental research on the composition and properties of textile fibers."

THE Faraday Medal of the British Institution of Electrical Engineers has been awarded to Sir Archibald Page, past president of the institution.

THE Council of the Physical Society, London, has awarded the Charles Chree Medal and Prize for 1943 to Professor (now Colonel) B. F. J. Schonland and the Duddell Medal for 1942 to Dr. C. R. Burch. Colonel Schonland, formerly professor of physics at Cape Town and afterwards director of the Bernard Price Institute of Geophysics at Johannesburg, is now in Great Britain engaged in scientific work in connection with the war. Dr. Burch, formerly of the Research Department of the Metropolitan-Vickers Electrical Company, has continued his work in the physics laboratories of the Imperial College and the University of Bristol.

THE doctorate of science will be conferred on April 18 at the commencement exercises of the University of Dayton on Jeanne S. Schwengel, research associate of the Academy of Natural Sciences, Philadelphia, in recognition of "notable contributions to science in the field of conchology."

F. C. LEA, formerly professor of engineering at the University of Sheffield, has been elected president of the British Institution of Mechanical Engineers.

THE following members of the faculty of Yale University will retire at the close of the academic year: Dr. Treat B. Johnson, Sterling professor of chemistry; Dr. Herman H. Chapman, Harriman professor of forest management; Dr. Richard S. Kirby, associate professor of engineering drawing, and James K. Whittemore, associate professor of mathematics.

DR. DAVID J. DAVIS, professor and head of the department of pathology, bacteriology and public health and dean of the College of Medicine of the University of Illinois, will retire on September 1.

SIR FARQUHAR BUZZARD, regius professor of medicine at the University of Oxford, will retire in April. *The British Medical Journal* reports that his friends and colleagues wish to commemorate his work, and that a representative committee has suggested that his portrait should be painted and that a Buzzard scholarship or prize in medicine should be endowed.

DR. WALTER E. SULLIVAN, professor of anatomy and head of the department of the University of Wisconsin, is serving for six months as visiting professor of anatomy at the School of Medicine of Washington University, St. Louis.

DR. BERNARD H. KNIGHT, research officer in highway engineering at the University of the Witwatersrand, Johannesburg, has been appointed to the newly established chair of highway engineering in that university, the appointment to take effect on April 1. *Nature* states that it is believed that this chair of highway engineering, which is tenable in the department of civil engineering, is the first of its kind to be founded in the British Empire outside Great Britain.

DR. ALASTAIR FRAZER, reader in pharmacology in the University of Birmingham, has been appointed professor of pharmacology, a new chair recently established at the university.

DR. HENRY C. SHERMAN, professor of chemistry at Columbia University, has been appointed head of the newly established Bureau of Human Nutrition and Home Economics of the U. S. Department of Agriculture.

DR. ALBERT L. ELDER, of the department of chemistry of the College of Liberal Arts of Syracuse University, who has indefinite leave for service with the War Production Board, has been made its chief chemical adviser. His previous position was that of principal industrial analyst.

DR. FRANKLIN CHURCH BING, formerly secretary of the Council on Foods and Nutrition of the American Medical Association, has been appointed a director of the American Institute of Baking.

DR. JOHN W. CROSSON, since 1940 director of the bureau of industrial hygiene of the West Virginia State Department of Health, has become industrial consultant for Sharp and Dohme. He will join the medical research staff in Philadelphia.

J. A. STEERS, dean of St. Catharine's College, Cambridge, and university lecturer in geography, has been appointed adviser to the British Minister of Town and Country Planning on scientific matters connected with the preservation of the coast line.

DR. EARL B. WORKING, for the past twenty years a member of the staff of the department of milling industry of the Kansas Agricultural Experiment Station at Manhattan, plans to leave late this month for Port au Prince, Haiti. The Société Haitiano-Americaine de Developpement Agricole has received a grant-in-aid from the Board of Economic Warfare and, in cooperation with the Rubber Reserve Corporation, has undertaken the production of rubber from the Cryptostegia plant, a member of the milkweed plant family. Dr. Working will be director of chemical research for the rubber project and will have supervision of the research laboratory at Gonaives, Haiti.

DR. JERZY NEYMAN, director of the Statistical

Laboratory of the University of California, addressed on March 3 a joint meeting of the Yale Chapter of Sigma Xi and the Connecticut Chapter of the American Statistical Association in New Haven. His subject was "The Probabilities of Errors of the Second Kind and the Design of Experiments."

DR. CARL S. MARVEL, professor of organic chemistry at the University of Illinois, will deliver on April 2 at the University of Chicago the third annual lecture under the Julius Stieglitz Memorial Lectureship. He will take as his subject "The Structure of Vinyl Polymers."

DR. FRANCIS G. BLAKE, Sterling professor of medicine and dean of the Yale University School of Medicine, gave on January 28 the first annual Begg Society Lecture at the School of Medicine of Boston University on "Epidemic Diseases in Wartime."

DR. SAMUEL W. CLAUSEN, professor of pediatrics at the University of Rochester School of Medicine, delivered on March 18 at the New York Academy of Medicine the sixth Harvey Society Lecture of the current series. His subject was "The Absorption of Vitamin A and its Storage in the Tissues."

DR. VINCENT DU VIGNEAUD, professor of biochemistry and head of the department, Cornell University Medical College, New York, gave an address on March 18 before the Chicago Section of the American Chemical Society. He spoke on "The Chemical Nature of Biotin."

THE annual conference of the Institute of Food Technologists for 1943 will be held in St. Louis on June 2, 3 and 4. The Hotel Statler has been selected as headquarters. All meetings, under the presidency of Dr. R. C. Newton, will be related to the problem of food processing during the war effort. On the evening of June 2 the Nicholas Appert Medal Award will be made. All registered members will attend the opening of the St. Louis Municipal Opera on the evening of June 3 as guests of the St. Louis Section, of which Dr. E. H. Harvey is general chairman.

A CONFERENCE, sponsored by the New York Academy of Sciences, on Parasitic Diseases and American Participation in the War, presided over by Dr. Horace W. Stunkard, of New York University, was held on March 13. The speakers were Dr. Lowell T. Coggeshall, of the School of Public Health of the University of Michigan; Dr. Norman R. Stoll, of the Rockefeller Institute for Medical Research, Princeton, N. J.; Dr. Robert Matheson, of Cornell University, and Dr. Thomas T. Mackie (Lt. Colonel), of the Army Medical School, Washington, D. C.

THE three hundred and ninety-fourth meeting of the American Mathematical Society was held at Columbia University on February 27. The attendance was approximately two hundred, including one hundred sixty-six members of the society. Two addresses were given by invitation of the Program Committees: "Transformation Groups and Spheres," by Professor Deane Montgomery, of Smith College, and "Some Topics in the Theory of Semi-linear Transformations," by Professor Nathan Jacobson, of the University of North Carolina. Professor Montgomery's address had been scheduled originally for the annual meeting, which was cancelled on account of transportation difficulties. There were also four sessions at which twenty-two contributed papers were presented on analysis, algebra, applied mathematics, geometry and statistics. Thirteen additional papers were presented by title. The council of the society held a meeting at noon on Saturday, at which, among other things, a report of the War Policy Committee was approved.

THE annual meeting of the International Association for Dental Research was held in Chicago on March 13 and 14.

APPLICATIONS for grants from the Cyrus M. Warren Fund of the American Academy of Arts and Sciences should be received by the chairman of the committee, Professor Frederick G. Keyes, of the Massachusetts Institute of Technology, not later than April 15. Grants are made in aid of chemical research, generally for apparatus or supplies, or for the construction of special facilities needed for research in chemistry or in fields closely related to chemistry. Grants are not awarded for salaries, and on account of limited resources the amount of a grant to an individual is seldom in excess of $300. Application blanks may be obtained from the chairman upon request.

Two fellowships are offered by the Cinchona Products Institute of New York for clinical or pharmacological research on quinine or the other alkaloids of cinchona. They carry a yearly stipend of $2,000, plus necessary laboratory or routine expenses. Further details may be secured from Cinchona Products Institute, Inc., 10 Rockefeller Plaza, New York.

A RESEARCH assistantship in petroleum physics has been established by the Gulf Oil Corporation at the Massachusetts Institute of Technology. The recipient must qualify for a tuition scholarship and be a candidate for an advanced degree in the department of physics. The stipend is $1,100 per school year, subject to renewal at the end of nine months under an accelerated program. Applications should be made before April 1 on forms obtained from the admissions office.

DISCUSSION

OCCURRENCE OF THE PLIOCENE ANTELOPE, ILINGOCEROS, IN NEVADA

UNTIL recently the only known occurrence of the peculiar twisted-horn antelope, *Ilingoceros,* was that recorded by Dr. J. C. Merriam[1] from the Thousand Creek Pliocene deposits of northwestern Nevada. During the past 30 or more years much interest has been manifested by students of fossil mammals in the paleontological history of the Antilocapridae. The family has come to be recognized as having a unique position in American animal life. Thus, its representation to-day by a single genus, *Antilocapra,* stands in decided contrast to the great diversity of type which characterized the family in former geologic time. The existence of many different kinds of antelopes in the past is exemplified by the several extinct genera in Pleistocene faunas, but even more so by the unusual and even bizarre creatures of the Pliocene.

Although the extended studies which have been conducted on the later Tertiary faunas of western North America and their correlation have brought to light new genera of antelopes, it is rather odd that no new occurrences of *Ilingoceros* have been found.

Pliocene localities at Smith Creek in central Nevada, yielding fossil mammalian remains, were discovered by Stock and Furlong about 1928. Later, in 1931 and 1934, summer field parties from the California Institute of Technology conducted further explorations in this region and obtained additional materials. No complete survey has been made as yet of the fossil assemblage. R. W. Wilson[2] published a report on the rodents in the fauna, and on the basis of this study correlated the Smith Creek fauna with that from the middle Pliocene Thousand Creek beds.

A recent survey of the larger fossil mammals from the Smith Creek Pliocene in the paleontological collections of the California Institute of Technology brought to light a fragment of a frontal bone with the basal part of the horncore and roof of the orbit. On the basis of size, proportions and morphological characters shown by this specimen, No. 795, C. I. T. Coll., there can be no doubt that it belongs to *Ilingoceros.* Associated limb elements confirm this conclusion. Hence the geographic range of the genus is extended, at least locally in what is now the Great Basin region, and the identification lends further support to Wilson's view that the Smith Creek and Thousand Creek faunas are closely related in time.

E. L. FURLONG

CALIFORNIA INSTITUTE OF TECHNOLOGY

[1] J. C. Merriam, *Univ. Calif. Publ., Bull. Dept. Geol.,* Vol. 5, No. 22, pp. 319–330, 7 figs., 1910.

[2] R. W. Wilson, *Carnegie Inst. Wash. Publ.* No. 473, pp. 15–34, 2 pls., 1936; *Carnegie Inst. Wash. Publ.* No. 487, pp. 21–73, 1937.

HALOGETON GLOMERATUS, POISONOUS TO SHEEP

Halogeton glomeratus (Chenopodiaceae) has been reported to have established itself in northeastern Nevada in 1935 and has spread rapidly over the range.

In an area a few miles south of Wells, Nevada, there have been heavy sheep losses during the past two years which have been suspected to have been due to this plant.

Examination of a sample of the plants from the area on which poisoning has recently occurred has disclosed the presence of large quantities of oxalates, which has justified the suspicion that this plant was the active agent.

Chemical analysis showed the dried sample to contain total oxalates equivalent to 19 per cent. anhydrous oxalic acid. Oxalates in water-soluble form were found equivalent to 11 per cent. anhydrous oxalic acid.

The presence of calcium oxalate crystals may be easily demonstrated by shaking the dry ground plant with water when the calcium oxalate may be seen at the bottom of the liquid, the greater part of the plant tissue floating to the surface.

The presence of several other crystalline compounds was observed with the compound crystals of calcium oxalate. These will be investigated further.

The occurrence of oxalates in members of the Chenopodiaceae is well known but in the quantities found in this plant, somewhat unusual. No mention has been found in the literature of the occurrence of oxalates in *Halogeton glomeratus* nor of possible poisonous properties to animals eating the plant.

M. R. MILLER

CHEMICAL LABORATORY,
NEVADA AGRICULTURAL EXPERIMENT STATION,
UNIVERSITY OF NEVADA

WAR WORK IN THE HIGH SCHOOLS

THE high schools of the country are now asked to train the boys and girls in a way never before attempted. Workers of all kinds are now in demand. Much of this work requires thought and skill. They must acquire the ability to think straight and to work steadily and accurately in the shortest possible time. Industry, agriculture, business and the armed forces are all in need of them.

Young people are asked to prepare immediately for one of five major needs. (1) The armed forces need men with practical technical training. An increase in the armed forces of approximately three million men is expected by the end of 1943 or early in 1944. The men needed most are those with specific

types of preparation. (2) A continuous supply of scientifically trained workers is demanded. These include especially physicists, meteorologists, radio engineers, all other types of engineers and medical men. (3) The war industries have definite and immediate need for men with practical technical training. (4) Industry and civil life need a continuous supply of physicists, engineers, doctors, chemists and biologists, both for war production and for essential civilian needs. (5) Agriculture and business must have the continuous services of boys and girls. The more training these young people have the more efficient they become for taking the places usually held by older and more experienced people.

Five pre-induction courses have been presented by the War Department and the U. S. Office of Education in elementary electricity, elementary machines, elementary shopwork, automotive machines and radio. Emphasis on these courses will prepare many students for much-needed work, but some students should prepare to go further while others not suited for work of this type must select other useful fields. It is the business of the high school to classify the students and prepare each for the type of this essential work for which he is best adapted.

The Cooperative Committee on Science Teaching has made a definite study of each of the four great science groups—physics, mathematics, biology and chemistry—and offers suggestions on the best courses for the high schools to pursue to meet the changes demanded by the war. These recommendations are published in the February issue of *School Science and Mathematics*. Copies of the report may be obtained by applying to Robert J. Havighurst, The University of Chicago.

GLEN W. WARNER
WOODROW WILSON CITY COLLEGE,
CHICAGO

SCIENTIFIC BOOKS

COMPARATIVE VERTEBRATE ANATOMY

Comparative Vertebrate Anatomy. By LIBBIE HENRIETTA HYMAN. 2nd edition. University of Chicago Press. i–xx, 1–544 pp. 136 figs. 1942. $3.50.

IT is hardly possible to review a book properly without also undertaking some sort of analysis of the purpose for which it was written. This is all the more desirable in the present field, because books for use in comparative anatomy classes have not in the past proved entirely satisfactory.

Comparative anatomy of vertebrates is a broad field that it is really impossible to segregate from embryology. It covers the range of vertebrate variation and necessitates more or less dissection—a time-consuming occupation. In breadth it might well be compared with History. Suppose, in his progress from kindergarten to Ph.D., one had not more than 90 hours to cover the extent of History—Ancient, Roman, English, French and United States combined. And yet the student is usually given in comparative anatomy a breadth of field and a wealth of detail that it would take him years to cover adequately.

The only students needing much detailed knowledge of comparative anatomy are those expecting to make a career of either zoology or medicine. To the very much larger percentage of other students the subject is merely an academic discipline the minutiae of which they will soon forget. For such of these as elect it, the presentation should either be combined with embryology, or in a condensed course of one semester, stressing principles and bearing somewhat the same relation to the topic as the course in physiology and anatomy for trained nurses does to these subjects as offered to the student of medicine. From the standpoint of the medical student, at least, what is desired is a working understanding of the phylogeny of the systems—how the parts of the body get that way—rather than a precise knowledge of the anatomy of dogfish, mud puppy or tortoise.

Miss Hyman is a gifted writer of text-books, as she demonstrated in her "Laboratory Manual for Comparative Vertebrate Anatomy" (1922), a book that has been very widely used. The volume under review is a second edition of this, some 30 per cent. larger, with parts rewritten and amplified, and almost twice as many figures. It is now less frankly a dissecting manual. Few, I think, can find fault with the author's plan of procedure as set forth in her prefaces. She is fully aware of the difficulty in presenting such a broad subject in a limited space, particularly by one whose chief research interests lie in the field of invertebrates. Her approach, from the systemic rather than from the type aspect, is in accordance with progressive ideas generally entertained on the subject.

The dogfish, mud puppy, turtle, rabbit and cat are the forms receiving particular consideration, but some attention is paid to other kinds as well. Birds are omitted, as they are so specialized that they hardly belong in a work of this scope. It is probable that the turtle could also be dropped, with some benefit to the student. Both rabbit and cat, especially the latter, are firmly entrenched in zoological curricula, on the basis of availability. In some respects they are entirely satisfactory, but in others, as skeletal and muscular systems, they are quite specialized. Some col-

leges have already found it decidedly worth while, in spite of increase in cost, to use the macaque monkey exclusively for mammalian dissection. This is so very desirable, from the standpoint of the premedical student, that it would have been a progressive step to substitute this mammal for rabbit and cat.

Workers in the phylogeny of vertebrates, including anatomists and embryologists, have been increasingly aware during recent years that one of the greatest needs in this general field is a scrutiny and revaluation of all the old concepts laid down dogmatically several scores of years ago and copied in one generation of text-books after another. The old masters were most gifted zoologists, but the style then was to build, at all costs, complete evolutional and developmental pictures, filling voids with what they believed to be plausible interpretations. Recent books have far too many old illusions interlarded among proven facts. Although Miss Hyman specifically recognizes this situation, she, nevertheless, has succumbed to the temptation of presenting complete, rule-of-thumb developmental pictures. The temptation is great and I have done the same myself, frequently.

One using this book will, I think, wish for more illustrations of a factual nature. There is a sufficient number of embryological figures, and of some other categories, but still other subjects are scantily pictured. Although the turtle is the reptile stressed, none of its musculature is shown, but instead, that of the tuatara, alligator and reconstructions of extinct reptiles. The student needs facts shown, and of forms that he is able to observe. There is no illustration of the peripheral nerves, although the limb plexuses, for instance, may be much more clearly pictured than described; there are no figures of the eye, *et cetera*. The anatomy of hand and foot is of much importance, and yet consideration of the soft parts of the limbs ends at wrist and ankle.

Much of the criticism that might with justice be aimed at this book would apply to any short treatise on the subject. The fact remains, however, that the author has given us the most useful text-book on comparative vertebrate anatomy so far available in the English language.

A. BRAZIER HOWELL

COLLEGE CHEMISTRY

Essentials of College Chemistry. By NORMAN KHARASCH and HELEN S. MACKENZIE. xii + 513 pp. New York: D. Van Nostrand Company, Inc. 1942. $3.50.

UNDER this title the authors, both staff members of the Illinois Institute of Technology, have produced a very readable, well-indexed introduction to general chemistry. Their style is clear, direct and unhurried. The illustrations, consisting of 99 figures and 48 tables, are pertinent and well-balanced. The value of the text is enhanced by the use of large, clear type, non-glossy paper and durable binding.

Faced with the necessity of choosing from the vast accumulation of introductory material, the authors have placed extra emphasis upon the structure of matter, and by their omissions and order of arrangement constantly remind us that success lies around many corners.

Each of the twenty-three chapters includes selected references; twenty of them are followed by exercises and six by summaries. Some of the others could have been similarly treated to advantage. The reference book list records but seven general chemistry texts.

Separate title pages divide the text as follows: Introduction; The States of Matter; The Theory of Ionization; The Non-Metals; The Metals; Introduction to Organic Chemistry; The Ceramic Industries; Appendix; Index. These sections do not necessarily indicate their scope. For example, the section titled "The States of Matter" comprises eight chapters, among them, "Atoms-Molecules-Chemical Changes," "The Velocity of Chemical Reactions" and "The Periodic Classification of the Elements." The appendix includes an "Outline of the History of Chemistry," "Rules of Nomenclature for Inorganic Compounds," "Solubilities of some Salts at 20° C" and "Vapor Pressure of Water." A "Table of International Atomic Weights" appears on the inside back cover. The excellent chapter on "Ceramics" was written by an invited specialist in the field.

Some teachers will object to the compression within a single chapter of oxygen, ozone, hydrogen, hydroxides, oxidation, reduction, endo- and exothermic reactions, the activity series of the metals, valence and chemical equivalents. These 22 pages are busy ones indeed. Other teachers will be delighted to find 20 per cent. of the text devoted to carbon and organic chemistry—trimmed freely with structural formulas for sugar and vitamins and such substances as mercurochrome, alizarine, salvarsan and phenolphthalein.

Strong features of the text are acids, bases, hydrolysis, chemical equilibrium, isomerism and structural formulas. The authors employ delightful analogies and techniques to make their points clear. The same strength does not carry over into the field of applied chemistry. And it is unfortunate that the text should be marred by inaccuracies and inconsistencies.

Explosives and combustible mixtures are confused. "△" over an equation is used promiscuously to indicate either endothermic action or elevated temperature. Electrolytic equations are written first $2\,Cl^- - 2\,e \rightarrow 2\,Cl$ and then $2\,Br^- \rightarrow 2\,Br + e$.

According to the authors, "the free metal (barium) is not prepared commercially and has no uses"; the fluorine molecule is "stable at all temperatures"; "the oxide (of aluminum) is infusible"; "the decomposition of potassium chlorate into potassium chloride and oxygen . . . (is) . . . endothermic"; "barium melts at 850° C and boils at 1140°."

R. A. BAKER

Brief College Chemistry. By LEON B. RICHARDSON and ANDERW J. SCARLETT. vi + 385 pp. 128 figs. New York: Henry Holt and Company. 1942. $3.00.

WRITTEN in the refreshing style already associated with these authors, this brief text is no scissors-and-paste abstract, but a paraphrase of their earlier works. Because it is scholarly it happily stands apart from those "science survey" texts which dilute science to the level of the tabloid.

There are five introductory chapters on valence, atomic structure and the periodic table; eight chapters on physical chemistry, including energy, states of matter, equilibrium—introduced probably too early for an elementary course—chemical calculations, the ionic properties of solutions, and a logical use of the Brønsted treatment of acids and bases; eight chapters on the non-metals and seven on the metals, with two concluding chapters on organic chemistry. Sandwiched into physical chemistry is the chemistry of water and its constituent elements; electrochemistry is interposed between aluminum and iron; colloids are inserted between phosphorus and carbon. Although these special topics are arbitrarily located, at least they are consistently handled.

This brief, elementary, but authoritative text should supplant its several inferior predecessors.

HUBERT N. ALYEA

Introductory College Chemistry. Second edition. By HORACE G. DEMING. 521 pp. 176 figs. New York: John Wiley and Sons, Inc. 1942. $3.00.

Now written in collaboration with Professor Hendricks, this well-known, attractive and particularly reliable elementary text has been entirely reset in larger, clearer type. Chapter headings remain the same as in the first, 1933, edition. Cuts of modern industrial products and processes, new sections on the structure of liquids and solids, x-ray studies, photography, plastics, vitamins and animal nutrition considerably improve and modernize the subject-matter.

HUBERT N. ALYEA

PRINCETON UNIVERSITY

SPECIAL ARTICLES

INCREASED SYNTHESIS OF p-AMINOBENZOIC ACID ASSOCIATED WITH THE DEVELOPMENT OF SULFONAMIDE RESISTANCE IN STAPHYLOCOCCUS AUREUS

THE means by which bacteria become resistant to the bacteriostatic action of the sulfonamide drugs has remained obscure, although this phenomenon has been known for several years[1] and has been observed in a number of bacterial species.[2,3,4,5,6] While a sizable body of information on the technique of development of resistance *in vitro* has accumulated and its clinical analogue has been described, careful study has failed to disclose significant differences (in morphology, carbohydrate fermentation, growth rates, virulence, etc.) between sulfonamide-resistant and susceptible organisms. With the failure to solve the problem by the use of orthodox bacteriological procedures, the method of attack has shifted to the biochemical.

It has been postulated[7] and indirect evidence suggests[8,9,10] that increased p-aminobenzoic acid (PAB) synthesis by sulfonamide-resistant organisms may account for their lack of sensitivity to sulfonamides. This explanation has not been proved heretofore, since no adequate test for PAB was available. The development by Landy and Dicken[11] of a suitable microbiological method for the determination of PAB made possible a quantitative comparison of the amounts of PAB synthesized by sulfonamide-sensitive and resistant bacteria. Evidence presented in this report indicates that sulfonamide-resistant strains of *Staphylococcus aureus* produced significantly more PAB than the corresponding sensitive strains.

The cultures investigated were *S. aureus* strains 7 and 14 supplied by Dr. Wesley Spink, of the University of Minnesota Medical School, who has described their susceptibility to sulfonamide inhibition *in vitro*.[12]

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[1] I. H. MacLean, K. B. Rogers and A. Fleming, *Lancet*, I: 562, 1939.
[2] C. M. MacLeod and G. Daddi, *Proc. Soc. Exp. Biol. and Med.*, 41: 69, 1939.
[3] L. Westphal, R. L. Charles and C. M. Carpenter, *Ven. Dis. Inform.*, 21: 183, 1940.
[4] E. Strauss, J. H. Dingle and M. Finland, *Jour. Immunol.*, 42: 313, 1941.
[5] E. Strauss, J. H. Dingle and M. Finland, *Jour. Immunol.*, 42: 331, 1941.
[6] H. N. Green, *Brit. Jour. Exp. Path.*, 21: 38, 1940.
[7] D. D. Woods, *Brit. Jour. Exp. Path.*, 21: 74, 1940.
[8] C. M. MacLeod, *Jour. Exp. Med.*, 72: 217, 1940.
[9] H. N. Green and F. Bielschowsky, *Brit. Jour. Exp. Path.*, 23: 1, 1942.
[10] G. S. Mirick, *Jour. Clin. Invest.*, 21: 628, 1942.
[11] M. Landy and D. M. Dicken, *Jour. Biol. Chem.*, 146: 109, 1942.
[12] J. J. Vivino and W. W. Spink, *Proc. Soc. Exp. Biol. and Med.*, 50: 336, 1942.

Resistance had been induced by exposure of the parent strains to increasing concentrations of sulfathiazole. These cultures were maintained by us in a chemically defined, PAB-free medium[13] which supported growth equivalent to that obtained with meat infusion broth. This medium was used in all the following experiments. The results of the determination of the sensitivity and resistance to sulfonamides of the *S. aureus* strains are given in Table I. Although

TABLE I

BACTERIOSTATIC ACTION OF THE SULFONAMIDE DRUGS ON PARENT AND RESISTANT STRAINS OF STAPHYLOCOCCUS AUREUS GROWN IN SYNTHETIC MEDIUM

Sulfonamide drug	Staphylococcus aureus 7		Staphylococcus aureus 14	
	Parent inoculum 620 org.	Resistant inoculum 315 org.	Parent inoculum 1860 org.	Resistant inoculum 124 org.
Sulfanilamide	1 = N 100 = P 500 = C	2,000 = N 12,500 = P 15,000 = C	50 = N 500 = P 1000 = C	20,000 = N
Sulfaguanidine	1 = N 10 = P 500 = C	2,000 = N 20,000 = P	10 = N 500 = P 1000 = C	20,000 = N
Sulfadiazine	10 = N 50 = P 100 = C	10,000 = N 12,500 = C	10 = N 50 = P 100 = C	10,000 = N 12,500 = C
Sulfathiazole	0.1 = N 0.5 = P 1.0 = C	1,000 = N 4,000 = P 8,000 = C	0.5 = N 1.0 = P 10 = C	4,000 = N 6,000 = P 8,000 = C

The concentration of sulfonamides is expressed in γ per 10 cc culture.
N = None, no inhibition of growth, growth same as control.
P = Partial inhibition of growth compared with control at 72 hours.
C = Complete inhibition of growth. No growth or cloudiness in 72 hours.

originally exposed only to sulfathiazole, it is evident that a high degree of resistance to the other sulfonamides has been established as well in both strains of *S. aureus*. More marked resistance to sulfadiazine and sulfathiazole than to sulfanilamide and sulfaguanidine appears to have been developed. It is possible, however, that this is more apparent than real, since fairly high concentrations of sulfanilamide and sulfaguanidine are tolerated by the parent strains while they are more sensitive to sulfadiazine and particularly to sulfathiazole.

For the determination of PAB synthesis by the parent and resistant strains of *S. aureus*, the cultures were transferred a number of times in the synthetic medium, thus reducing the possibility of carrying over any PAB. Plate counts after 24 hours incubation revealed that the populations of the four cultures were approximately equal. Small inocula of the cultures, averaging several thousand organisms, were introduced into 50 cc volumes of synthetic medium, incubated for 24 hours at 37° C, filtered through Seitz filters and the filtrates autoclaved and assayed for PAB by the method of Landy and Dicken.[11] The results of the assay of the *S. aureus* culture filtrates[14] are given in Table II. It will be seen that the data

TABLE II

p-AMINOBENZOIC ACID CONTENT OF STAPHYLOCOCCUS AUREUS FILTRATES AT VARYING ASSAY LEVELS
Parent Strains

Amount of filtrate per assay flask	p-Aminobenzoic acid			
	Found		Content	
	No. 7	No. 14	No. 7	No. 14
cc	γ	γ	γ per cc	γ per cc
1.00	.042	.047	.042	.047
0.50	.024	.024	.048	.048
0.25	.014	.013	.056	.051
0.10	.005	.005	.050	.050
Average			.049	.049

Resistant Strains

Amount of filtrate per assay flask	p-Aminobenzoic acid			
	Found		Content	
	No. 7	No. 14	No. 7	No. 14
cc	γ	γ	γ per cc	γ per cc
0.025	.080	.082	3.20	3.28
0.010	.033	.033	3.30	3.30
0.005	.016	.017	3.20	3.40
0.0025	.008	.009	3.20	3.60
Average			3.22	3.40

are in good agreement both as regards PAB content at various levels of assay and in the amounts found for strains 7 and 14. The quantity of PAB produced by resistant strains in contrast to that by parent strains is particularly impressive.

Since PAB was found in the culture filtrates in considerable amounts it was deemed advisable to measure its concentration by chemical as well as by microbiological means. Using the Litchfield-Marshall colorimetric test,[15] with crystalline PAB as the standard, values were obtained which were in fair agreement with those obtained by microbiological assay (Fig. 1). It should be pointed out that the diazo reaction could be employed here only because relatively large quantities of PAB were present,[16] since the method does not possess the sensitivity characteristic of the microbiological assay. It is well known that the chemical test is not specific for PAB, but is a measure of the concentration of primary aromatic amines.

S. aureus cultures were grown in the presence of

[13] The medium of M. Landy and D. M. Dicken, *Jour. Lab. and Clin. Med.*, 27: 1086, 1942, omitting sodium acetate, asparagine, guanine, xanthine and uracil. pH is readjusted to 7.5.

[14] Comparative assays performed on *S. aureus* filtrates and acid hydrolyzed whole cultures revealed that the bulk of PAB produced is secreted into the medium, since the filtrates contained almost as much as did the culture hydrolysates.

[15] J. T. Litchfield, Jr. and E. K. Marshall, Jr., SCIENCE, 88: 85, 1938.

[16] It is likely that the values obtained for PAB synthesis by the parent strains are in error since the quantity found for these strains by microbiological assay is known to be too small for detection by the chemical method.

sulfonamides[17] and the filtrates assayed for PAB. While the presence of sulfonamide in the culture filtrates made the subsequent quantitative measurement of PAB impossible (since sulfonamides inhibit the growth of *Acetobacter suboxydans*)[18] we were definitely able to ascertain that PAB synthesis was greater by resistant than by parent strains.

It is clear that sulfonamide-resistant staphylococci grown in a synthetic, PAB-free medium synthesize far more PAB than do the parent strains of the same

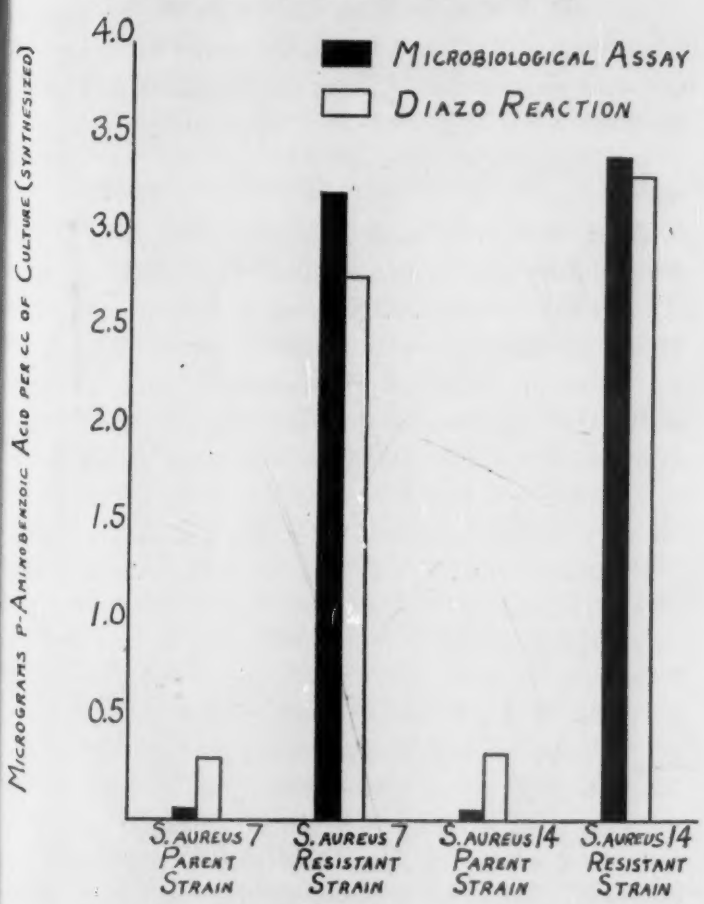

FIG. 1

organism. Under our test conditions this ratio is consistently in the order of 70 to 1. This great output stands in contrast to the amount of PAB synthesized by a variety of organisms representative of twelve bacterial genera.[19] None of these organisms studied produced PAB in quantities approaching that made by sulfonamide-resistant staphylococci. The average for all other organisms was 0.033 micrograms PAB per cc of culture, while the resistant staphylococci produced 3.3 micrograms of PAB per cc, or 100 times as much. Based on their inhibition by sulfonamides *in vitro* (Table I), the quantity of PAB synthesized by sulfonamide-resistant staphylococci is in considerable excess of that known to be required for reversal of the inhibitory action of the quantity of sulfonamide to which these organisms are resistant.[7]

Sulfonamide-resistant staphylococci continue to synthesize PAB far in excess of that normally produced by *S. aureus* for many generations following exposure to sulfonamides. It has been stated[6,20] that although sulfonamide fastness may be lost when only partially developed, well-established resistance is apparently retained indefinitely. Continued increased production of PAB by these resistant staphylococci may be considered as additional evidence for the permanence of sulfonamide fastness.

As a result of these and other data obtained from our PAB studies, we are of the opinion that the staphylococcus cell, becoming resistant to sulfonamides, undergoes fundamental changes in its PAB metabolism. That organisms may acquire resistance to sulfonamides without increasing their production of PAB is indicated by our studies[21] on *Escherichia coli, Vibrio cholerae, Shigella dysenteriae* and *Diplococcus pneumoniae*. Sulfonamide-resistant strains of these organisms failed to synthesize greater amounts of PAB than did their parent, non-resistant, strains. The possibility exists, however, that future investigation will reveal that these resistant organisms produce other "antisulfonamide metabolites" as yet unidentified, which do not support growth of our test organism, *A. suboxydans*.

SUMMARY

Sulfonamide-resistant strains of *Staphylococcus aureus* produce greater amounts of p-aminobenzoic acid than do their parent strains. This synthesis occurs both in the absence and in the presence of sulfonamides. The quantity of p-aminobenzoic acid synthesized by resistant strains appears sufficient to account for their resistance to sulfonamide drugs.

On the basis of this evidence, it is suggested that the development of ability to synthesize p-aminobenzoic acid in excess of the normal metabolic requirements, as a result of continued exposure to sulfonamides, explains the phenomenon of sulfonamide fastness in *Staphylococcus aureus*.

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[17] Sulfanilamide and sulfadiazine were employed. The amounts used varied from 1/10 to the maximum concentration which would still allow growth equal to that of controls (*cf.* Table I).

[18] M. Landy, N. W. Larkum and E. J. Oswald, *Jour. Bact.*, in press.

[19] M. Landy, N. W. Larkum and E. J. Oswald, *Jour. Bact.*, in press.

[20] L. H. Schmidt, C. Sesler and H. A. Dettwiler, *Jour. Pharmacol. and Exp. Therap.*, 74: 175, 1942.

[21] M. Landy, N. W. Larkum, E. J. Oswald and F. Streightoff, to be published.

ON THE CELLULAR DIVISION OF SPACE WITH MINIMUM AREA

THE problem of the division of space into congruent cells of minimum area has been studied previously. By means of the Calculus of Variations, one may demonstrate easily that such cells must have dihedral angles of 120°. The rhombic do-decahedron is a figure which possesses the characteristic of filling space and having all its dihedral angles of 120°, and on that account was considered for a long time as the

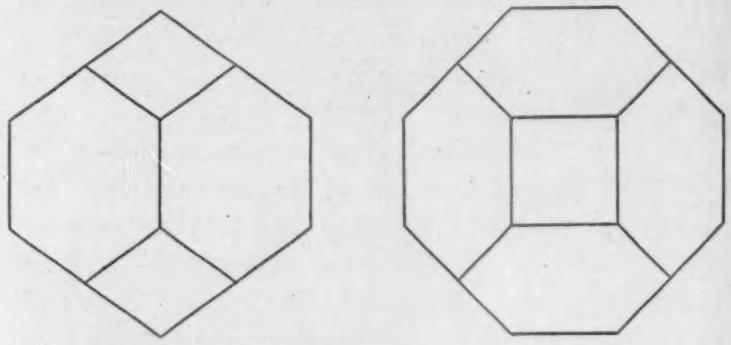

FIG. 1.

solution of the problem. One of the facts that raised a doubt as to whether it might be is that in nature, in all the cases of division of space in which the surface tends to diminish in area, there have been further hexagonal faces. The problem was resolved, however, in decisive form by Lord Kelvin.[1] Basing his argument on the physical experiments of Plateau on soap films, he deduced that the figure must be a curved 14-hedron similar to the planar, so-called orthic, 14-hedron. The planar 14-hedron can fill space, and for the same volume has less area than the rhombic do-decahedron, but its angles are not 120°.[2] By means of the Calculus of Variations Kelvin determined the form of this curved polyhedron of minimal area.

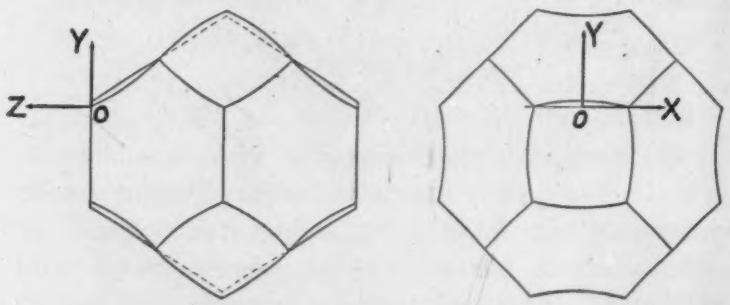

FIG. 2.

This problem interests greatly the biologists by its relation to the shape of cells in animal and plant tissues, in particular bean cells. Nevertheless, some biologists appear to doubt that the minimal 14-hedron of Kelvin has less area than the planar 14-hedron. Dr. Frederic T. Lewis, of the Harvard Medical School, who has studied the problem deeply and has been much interested in the solution, told me of this uncertainty as to the true solution. In order to dissipate the doubt of the biologists, I have not calculated the area of the 14-hedron of Kelvin, which would be quite a laborious task, but have constructed another curved 14-hedron with the same volume as the planar 14-hedron, and which has less area.

The form of construction, starting from the planar 14-hedron, is the following: in the plane of the square face with coordinates such as are indicated in Fig. 2, one takes a curve $y = k\,f(x)$ such that $f(-x) = f(x)$, $f\left(\frac{l}{2}\right) = 0$. One constructs a conical surface with vertex in the center of the adjacent hectagon with the curve as directrix. If one repeats this operation with all the edges of all the squares, the figure that one obtains has the same volume as the planar 14-hedron and can fill all space, as one sees easily from the symmetry of the figure (having all the symmetries of the planar 14-hedron). Its area will be a function of the parameter k, and to determine its minimum value is a very simple problem. For the demonstration, I have taken $l = 2$, and $f(x) = 1 - x^2$. The area is given by the formula

$$A(k) = 24 + 32\,k + 24\int_{-1}^{+1} \sqrt{3 - k\,[2(1+x^2) - k(1+10\,x^2+x^4)]}\,dx\,.$$

Since

$$\sqrt{a^2 - b} = a - \frac{b}{2a} - \frac{b^2}{2a\left(a + \sqrt{a^2-b}\right)^2};$$

and neglecting b in the denominator of the final term, one finds that the value of k which gives the minimum area is $k = 0.044$. Observing that

$$(2-k)k \leqq k[2(1+x^2) - k(1+10\,x^2+x^4)] \leqq (4-12\,k)k$$

for $-1 \leqq x \leqq 1$, one finds the area of the figure is:

$$A = 24 + 48\,\sqrt{3} - 0.1106 \pm 0.0001$$

which is 0.103 per cent. less than the area of the primitive polyhedron.

Dr. George D. Birkhoff has inquired concerning the interesting case $f(x) = 1 - |x|$ in which one has a polyhedron of 54 sides (but only 14 faces) which presents the required space-filling characteristics and for $k = 0.059$ is 0.086 per cent. less area than the original 14-hedron.

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[1] See Sir W. Thomson, "On the Division of Space with Minimum Partitional Area." *Philosophical Magazine and Journal of Science*, vol. XXIV (5), 1887.

[2] For exact dates and careful description, see D'Arcy W. Thompson book "On Growth and Form," Cambridge (Eng.) at the University Press, 1942.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN APPLICATION OF THE CONTROL CHART METHOD TO THE ANALYSIS OF FISHERIES DATA

IN a paper now in press as a Bulletin of the U. S. Fish and Wildlife Service[1] the writer has discussed the downward trend of the catch of Columbia River Chinook salmon since 1920 and has stated that the decline is doubtless an indication that the runs of this species are seriously depleted. Recently the same data have been studied by means of the control chart method and the results show so clearly that the productivity has dropped to a new and much lower level that it has seemed worth while to present a brief note amplifying the discussion in the bulletin.

The statistical analysis, or control chart, as developed by Shewhart,[2,3] Deming,[3] Simon[4] and others, has been applied chiefly to the control of quality of manufactured products but the same methods can be used in the analysis of other types of data, especially those involving time series. This application to the annual catch of Chinook salmon illustrates the value of the method in the field of fisheries biology.

Fundamentally the method has much in common with the analysis of variance and, in its more common application, involves systematic observations of a selected character and continuous analysis of the variations. It provides a convenient and rapid way of discovering the presence of heterogeneity in data, the causes of which, on further study, may be identified. The processes involved may then be controlled in the direction of the elimination of causes of undesired variability or, conversely, in the direction of the development of the causes behind an improvement. Ingenious tables facilitate the computations involved and the simple graphs used present the results in such a way that they may be readily extended, promptly analyzed and interpreted.[5,6,7]

Fig. 1 presents a series of graphs resulting from the application of this method to the analysis of the annual catch of Chinook salmon in the Columbia River

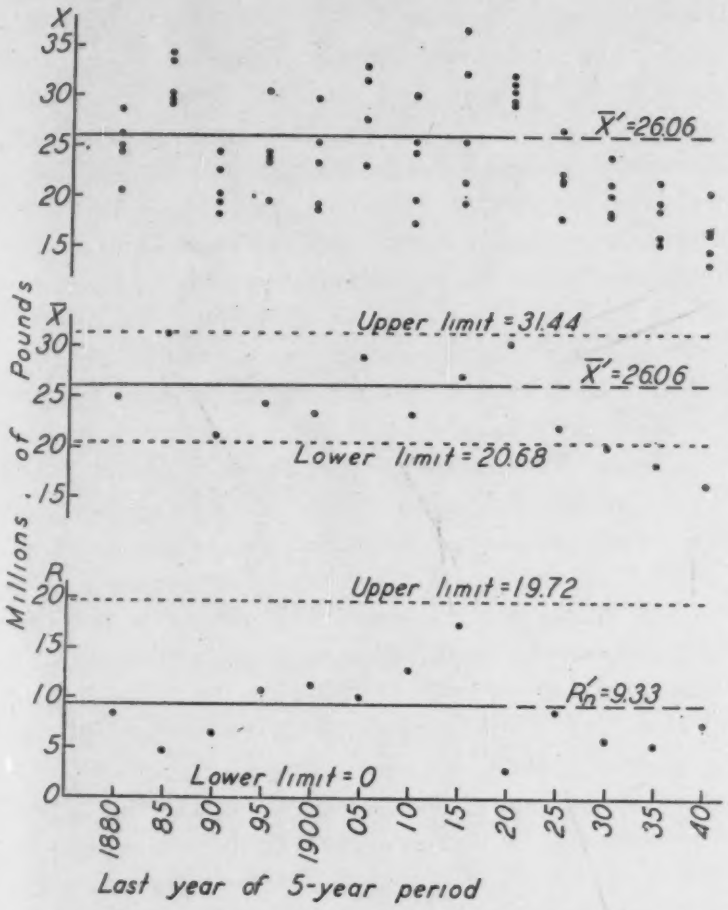

FIG. 1. Annual catch of Chinook salmon, Columbia River, 1876–1940. Analysis by control chart methods using the years 1876–1920 as standard.

from 1876 to 1940 (except for 1901, for which no data are available). The data are in pounds (estimated from pack data) and have been taken chiefly from Craig and Hacker[8] and from the Yearbooks of the Pacific Fisherman. The years have been grouped by 5's, making 13 groups which may be considered as consecutive samples. The ordinates in Fig. 1 correspond to these 5-year periods and the points on these ordinates show (1) the catch of each year in the period (X); (2) the mean annual catch for the period ($\bar{X}$); and (3) the range of the annual catches within each 5-year period (R).

Previous inspection of the data, particularly of the 5-year averages, had shown that the period since 1920 had been marked by a constantly reduced catch and, for this reason, the period from 1876 to 1920 was taken as the standard with which the catch for the years since 1920 was to be compared. The average catch during the 45 years from 1876 to 1920 was 26.06 million pounds, which is shown as the central, horizontal line in the X and $\bar{X}$ panels (labeled $\bar{X}'$). The average range of the catches during each 5-year period was 9.33 million pounds and is shown as the

[1] Willis H. Rich, "The Salmon Runs of the Columbia River in 1938." Contribution No. 7, Department of Research, Fish Commission of Oregon.

[2] W. A. Shewhart, "Economic Control of Quality of Manufactured Product." D. Van Nostrand Co., 1931.

[3] W. A. Shewhart, "Statistical Method from the Viewpoint of Quality Control." Edited by W. Edwards Deming. The Graduate School, Department of Agriculture, Washington, 1939.

[4] Leslie E. Simon, "An Engineers Manual of Statistical Methods." John Wiley and Sons, 1941.

[5] "Guide for Quality Control, Z1.1–1941," American Standards Association.

[6] "Control Chart Method of Analyzing Data, Z1.2–1941," American Standards Association.

[7] "Control Chart Method of Controlling Quality during Production, Z1.3–1942," American Standards Association.

[8] Joseph A. Craig and Robert L. Hacker, *Bulletin, U. S. Bureau of Fisheries*, No. 32, 1940.

central line in the R panel (labeled R'_n). The upper and lower limits as shown in the $\overline{X}$ and R panels are the limits set by adding to and subtracting from the mean values of these statistics ($\overline{X}'$ and R'_n) three times an estimate of their standard deviations. The estimation of these limits has been made from tables given in reference 7 for determining the "control limits" from the ranges. Assuming that the values of $\overline{X}$ and R are normally distributed, the probability of an individual value falling outside these limits solely as a result of sampling error would be only about .003.

It is apparent from the figure that there has been no significant change in the variability within 5-year periods—the points in the R panel cluster well within the limits. This is true even of the last four periods. In the case of the mean values, however (panel $\overline{X}$), the points for the last three periods are all below the lower limit and that for the period immediately preceding (including the years 1921–1925) is not far above the lower limit. The obvious interpretation is that the mean catches for at least the past three 5-year periods are significantly different from those of the period 1876–1920. If such a series of points outside the "control limits" were observed during the course of producing a manufactured product it would be taken as clear indication that something had gone wrong with the process and that things were getting rapidly worse. Even a single point outside the limits would be viewed with suspicion and an investigation started. There seems to be no reason to make a different interpretation of the data bearing on the runs of Columbia River Chinook salmon.

If such a control chart of the production of Chinook salmon on the Columbia River could have been presented in 1930 it would have shown that the 5-year period ending with that year was "out of control" and this should have been taken as a warning that something was wrong with the production process. As a result investigations could have been started to determine the causes of the reduced productivity and measures taken that might have prevented or at least delayed the progressive depletion that followed. As a matter of fact the need for such action was not felt because the true situation was not generally recognized. The catches had been small for a few years, it is true, but there had been poor years before and fishermen, canners and fisheries administrators alike took counsel of their hopes and looked forward to a return of the better catches that had prevailed so long. An occasional biologist recognized the danger and as early as 1925 the writer made the following statements: "The pack . . . has remained practically stationary for a number of years during which time the intensity of fishing has been increased. . . . We may assume, therefore, that the present intensity of fishing is too great and is resulting in a dangerous reduction of the reserve of breeding adults." And suggestions were offered for minimizing "the danger of seriously depleting the supply of fish before some indication of the imminence of such depletion has become apparent."[9] In the light of present knowledge it would appear that a control chart of the sort now available would have given exactly the sort of information that was needed.

If such information had been available in 1930 and if the production of Chinook salmon had been a commercial venture under statistical control is it too much to think that something effective might have been done promptly toward maintaining production at a higher level? It seems altogether probable that the low average level of the catches in the 5-year period ending with 1930 would have been a "basis for action." The scientific management of fishery resources is not quite so simple as maintaining quality in a production line of a factory but the importance of maintaining productivity of biological natural resources is much greater on account of the serious losses that result from depletion and the long time required for rehabilitation of once depleted resources.

This control chart method of statistical analysis may well prove to be of rather general application in biology and particularly in the management of fishery and wildlife resources. It is concise, positive, easy to apply and points out variations due to heterogeneity of data promptly while there is still a chance that the causes are still operative and can be identified.

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FISH COMMISSION OF OREGON AND
STANFORD UNIVERSITY

[9] Willis H. Rich, *Bulletin U. S. Bureau of Fisheries*, XLI, 1925.

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